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? Q27.628
(2)

consisting of:

Potassium dichromate	10.1 g
Potassium chlorate	15.4 g
Hydrochloric acid, 6N	25 ml
Water to	1 liter

for 15 seconds at 23°C. The strip was removed, rinsed with water and dried. There was no visible reaction with the protective metal stripe or with the underlying silver film.

Example 2

A silver film on polyethylene terephthalate support was overcoated with nickel film in a pattern of stripes using the same process described in Example 1. The nickel was deposited in three thicknesses: 265 A, 130A and 53A. The samples were bathed in the bleach solution of Example 1 as in Example 1 for 2 mintues at 23°C, rinsed in water and dried. In each case the unprotected silver appeared to react uniformly with the solution while the silver underlying the nickel stripes showed no sign of reaction.

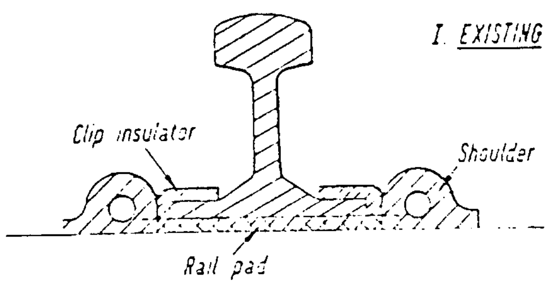
Disclosed anonymously (R1769)
15729

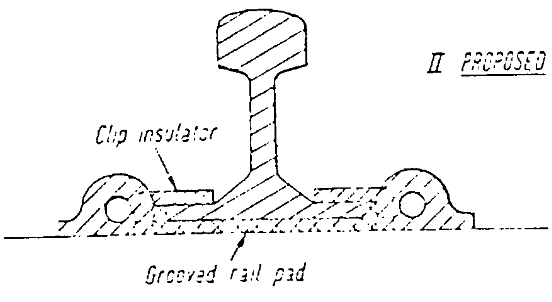
18702
Rail Pad

As shown in Figure 1, with existing rail fastening devices, the foot 1 of the rail 2 rests on pads 3 and is clamped in position by spring clips (not shown) on each side of the rail 2. The rail 2 is insulated from the fastening device by rail clip insulators 4 which are located between the clip and the foot 1 of the rail 2, and are bent down at one edge so that they also fit and insulate between the edge 5 of the rail foot 1 and the fastening shoulder 6. Thus the function of the pad 3 is solely to support the rail 2.

A problem arises in locating the rail accurately in the fastening. The clip insulators have to be held in place while the rail is barred over and this has proved to be an awkward, time consuming and risky operation.

By providing a pad 3 of channel section as shown in Figure 2, the pad 3 locates as well as supports the rail 2. Thus as indicated, the foot 1 of the rail 2 is located between the walls 7 of the channel-section pad 3, with modified insulators 4 as shown.





Sketch showing sections through Pandrol rail fastening
Showing – I Existing type pad and clip insulator
and II Proposed grooved pad and modified insulator
(Not to scale)
Note Spring clips omitted from sketch

Disclosed by London Transport Executive
15702

13715
Multilayered piezoelectric flexure device

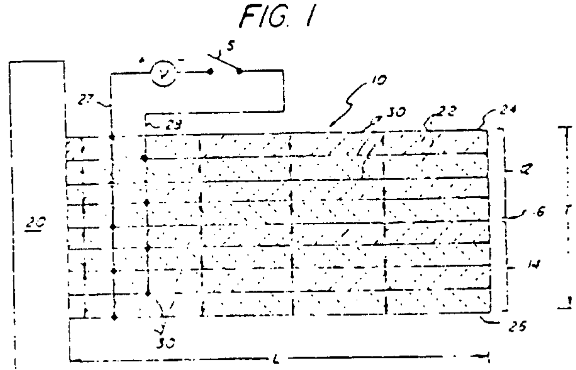
Disclosed herein are flexurally responsive piezo-electric devices of the unimorph and bimorph varieties. The piezoelectric component (s) of such devices is a multi-layered structure comprising a plurality of layers of a plastic piezoelectric film preferably polyvinylidene fluoride such layers being separated by conductive layers which serve as electrodes by which an electric field can be impressed across each film layer to cause a flexure action in the device.

Detailed description of preferred embodiments

Referring now to the drawings, Fig 1 is a cross-sectional view of a flexurally responsive piezoelectric device 10 of the bimorph variety. It comprises a pair of elongated, cantilever-mounted, piezoelectric members, 12, 14 which are bonded together along an interface 16 to form a sandwich-like structure of length L, thickness T, width W (see Fig 3). Note, the drawings are not drawn to scale inasmuch as the length-to-thickness ratio is not shown in proper proportion, typically, this ratio is between 10 and 1,000. In the drawings, the thickness dimension has been enlarged to better show the structure of each of the piezoelectric members 12, 14.

As indicated above, piezoelectric members 12, 14 extend outwardly, in a cantilever fashion, from a rigid support 20, one end of each of the members being rigidly clamped to the support. Each of the piezoelectric members comprises a plurality of layers 22 of a high polymer film, preferably polyvinylidene fluoride (PVF_2), which have been suitably poled to render them piezoelectric. The poling operation generally involves heating the film to an elevated temperature and subjecting it to an electric field for some minimum period of time. While processed in this manner, the electric dipoles in the film become aligned with the electric field lines, such field being applied across the thickness dimension of the film. The dipoles remain in this orientation after the electric field has been removed and the film has returned to ambient temperature. As regards PVF_2, the poling operation involves heating the material to approximately 100° and applying a field of approximately 3×10^5 volts/cm for a period of about 1 hour. For further details on the poling procedure for PVF_2, reference is made to the disclosures of US Patent No 3,894,198 and British Patent No 1,349,860. Thin films of PVF_2 which have been suitably poled to render them piezoelectric are commercially available from Kureha Chemical Industry, Co, Ltd in Tokyo, Japan. In Fig 1, it will be noted that adjacent films layers 22 of each piezoelectric member 12 and 14 happen to be poled in opposite directions the poling direction being indicated by the arrows. This difference in the poling direction of adjacent layers inherently results from the particular process used to form the layers, as described hereinbelow. Further, at interface 16, it can be seen that the bottommost film layer of member 12 is poled in the same direction as the top-most

FIG. 1



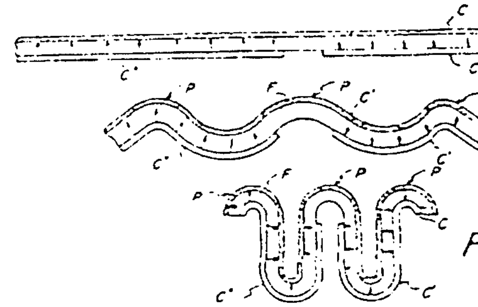
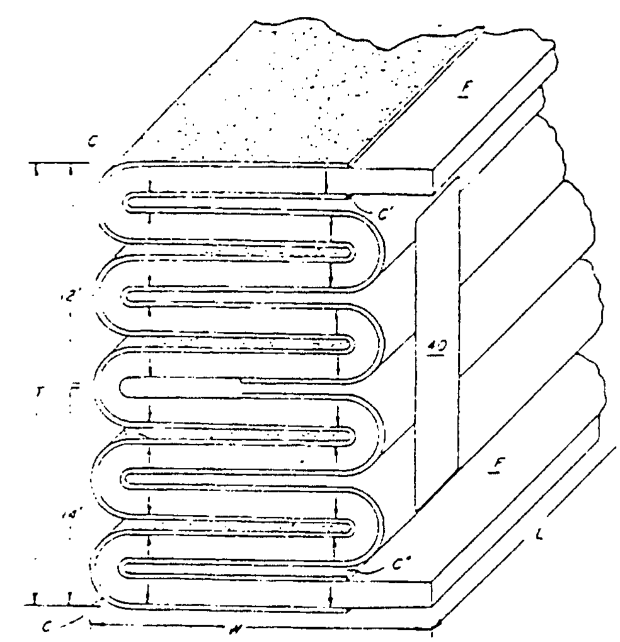


FIG. 2a

FIG. 2b

FIG. 2c

FIG. 3



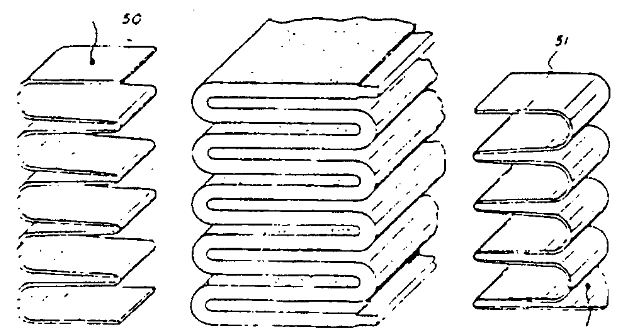


FIG. 4

film layer of member 14. The reason for this will become apparent from the ensuing further description.

Positioned between adjacent piezoelectric layers of each of the members 12, 14, as well as on the top and bottom surfaces 24 and 26 of the device, are electrically conductive layers 30. These conductive layers serve as electrodes by which an electric field can be applied across each layer. As shown in Fig 1, alternate conductive layers are electrically connected together by leads 27, 28 so that when a voltage is applied to these leads from a voltage source V, an electric field is applied across each piezoelectric layer. Note, the direction of the electric field lines, (ie from + to −) across each of the piezoelectric layers comprising member 12 is in the poling direction of the piezoelectric layer. Thus, when switch S is closed and the electric field is applied, all of the individual piezoelectric layers of member 12 will expand in length. As regards member 14, the direction of the applied field is in a direction opposite to the poling direction of each of the piezoelectric layers comprising member 14. Thus, when switch S is closed, piezoelectric member 14 will contract in length. The expansion of the multilayered member 12, coupled with the contraction of the multilayered member 14, causes the piezoelectric device to flex or bend. It should be understood that all of the layers 22 and 30 of each of the piezoelectric members 12 and 14 are bonded together by an adhesive, such as Eastman 910 cement, available from Eastman Kodak Company, Rochester, New York.

Each of the piezoelectric layers 22 comprises a nine micron (ie about 0.36 x 10^{-3} inch) thick film of PVF_2. The opposing planar surfaces of each PVF_2 film layer is coated, such as by vacuum deposition or sputtering techniques, with a thin layer of aluminum, say .08 microns (ie 3 x 10^{-6} inch) in thickness, such coatings serving as the conductive layers 30. Such metallized PVF_2 films can also be obtained from Kureha Chemical Industry Co. Ltd. As indicated above, maximum dimensional changes in a PVF_2 film can be achieved by applying a field of approximately 4 x 10^7 volts/meter of thickness. For a nine micron thick layer, this translates to a voltage requirement of only about 360 volts. Thus, though the overall thickness of each of the multilayered piezoelectric elements 12 and 14 as shown in Fig 1 is about 36 microns (ie 4 layers x 9 microns per layer) maximum dimensional changes in such a member can be achieved by applying a voltage of only 1/4 the voltage which would be required to produce maximum dimensional changes in a single layer which is 36 microns thick. Further, by designing each of the piezoelectric members of a bimorph as a multilayered structure, a substantial increase in the beam strength and, hence, driving force is achieved. It will be understood, of course, that each piezoelectric member 12, 14 may comprise substantially more layers than shown in the drawing. In fact, each member may comprise 30 or more layers of film.

In order to assemble a flexure device of the type described above, one surface of a relatively large sheet of PVF_2 film F is coated with an electrically conductive material C. (See Fig 2a) The opposite surface is similarly coated with a conductive material and a small strip at the center is uncoated to provide two spaced electrodes C' and C'', each covering slightly less than one-half the surface area of the lower surface of film F. Electrodes C' and C'' are positioned juxtaposed relative to the continuous electrode C. The PVF_2 film is poled by grounding electrode C and applying suitable voltages of opposite polarities to electrodes C' and C''. This results in poling one-half of the film sheet in one direction and the other half of the sheet in the opposite direction as indicated by the arrows. The sheet is then folded in a zig-zag fashion, as shown in Figs 2b and 2c, to form a plurality of pleats P. As a result of this folding operation, the PVF_2 sheet takes the form best illustrated in Fig 3. It will be noted that, as a result of this folding operation, adjacent layers of each of the elongated piezoelectric strips 12' and 14' appear to be poled in opposite directions, however, when a field is applied between electrodes C and C', or between C and C'', the film positioned therebetween will either expand or contact, depending upon the poling direction.

To maintain the folded layers contiguous after the folding operation, a hot-melt adhesive, such as manufactured by Black and Decker, is applied to the electrodes C, C' and C'' prior to the folding operation. A conductive paint strip 40 is applied to both sides of the folded, multilayer structure to assure that electrical continuity is maintained after the folding operation. To produce the flexure action from the piezoelectric device so produced, one of the painted conductive strips is grounded while an electric field is applied to the other. This results in a undirectional field across all of the PVF_2 layers. Since half of the layers are poled in the same direction as the applied field, and half are poled in the opposite direction, one half of the piezoelectric layers will expand and the remaining half will contract, the result being the flexure action.

Rather than form the bimorph structure from one continous sheet of PVF_2 film, one may, of course, prepare each of the multilayered piezoelectric members 12 and 14 separately, and then bond them together. Prior to such bonding, however, the multilayered members must be oriented with respect to each other so that they react in opposite senses in response to the same applied field.

In Fig 4, there is shown a pair of electrode structures 50 and 51 which are designed to make contact with the folded electrodes C, C' and C'' after the folding operation. In operation, voltage source V is applied to these electrode structures.

Various types of adhesive have been found useful for bonding adjacent layers together. Hot-melt glue has been found to be the easiest to control and work with. This glue is dissolved in toluene and applied to the surfaces of electrodes C, C' and C''. After applying the hot-melt glue to the electrodes, allowing it to dry, and folding the film in a zig-zag manner to form the multilayered structure shown in Figs 1c, 3 and 4, the multilayered structure is pressed together and placed in a warm oven to melt the glue and achieve the bonding effect. The effect of the bonding layers on the deflection-bandwidth product of the bimorph has been found to be negligible.

It will be appreciated that the method disclosed above can also be used in the manufacture of unimorph devices. In the unimorph flexure device, only one of the members 12, 14 in Fig 1 exhibits piezoelectric properties. Thus, in an electric field, the piezoelectric member will expand or contract, depending on the poling direction, and the other member, which is bonded to the piezoelectric member, will remain unaffected. The result is the flexure action. Obviously, the piezoelectric member of the unimorph may comprise the multilayered piezoelectric plastic film structure disclosed herein with reference to the bimorph type device, and the same manufacturing process can be used to make it.

Disclosed by J. Kelly Lee & Michael W Csontos
18715

18710
Poussoir pour montre électronique

Dans ce type de montres électroniques extra-plates, la liaison électrique

Patent Abstracts of Japan

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PUBLICATION DATE : 17-04-89

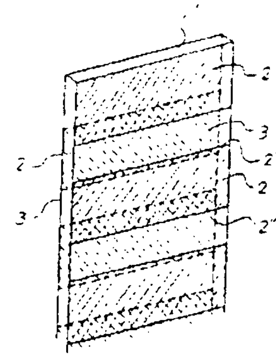
APPLICATION DATE : 09-10-87
APPLICATION NUMBER : 62255331

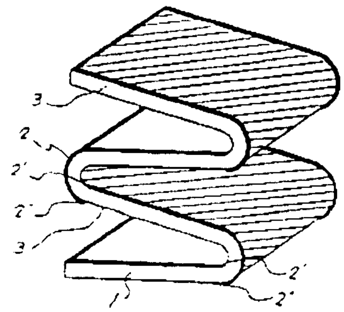
APPLICANT : MITSUBISHI KASEI CORP;

INVENTOR : OGURI YASUO;

INT.CL. : B28B 1/30 H01G 4/12 H01L 41/08

TITLE : MANUFACTURE OF CERAMIC LAMINATE





ABSTRACT : PURPOSE: To facilitate manufacture of a thin, laminated ceramic device with inner and outer electrodes formed at a time by baking a laminate in the form of a pleat made of a ceramic green sheet which is provided with electrodes on both surfaces.

CONSTITUTION: A green sheet is formed of an appropriate proportion of an organic binder, a plasticizer, and ceramic powder. One surface of the sheet is coated with electrode paste by spraying or screen printing, and dried. Similarly the other surface is also provided with electrodes. In this manner, a green sheet 1 with electrodes is prepared. The electrodes are preferably arranged in stripes at intervals narrower than the electrode width, and this arrangement is the same on both sides with some overlapping electrodes. This green sheet 1 is folded in such a manner that one end 2' of the electrode 2 is inside the fold and the other end 2" covers the outside of the fold completely. This makes it possible to easily make a thin laminate whose inner and outer electrode are simultaneously formed.

⑲日本国特許庁（JP）　⑪特許出願公開
⑫公開特許公報（A）　平1－97604
⑤Int.Cl.⁴　識別記号　庁内整理番号　㊸公開　平成1年(1989)4月17日
B 28 B 1/30　6865－4G
H 01 G 4/12　7924－5E
H 01 L 41/08　S－7342－5F　審査請求　未請求　発明の数 1　（全6頁）

㊹発明の名称　積層セラミックス製造法

㉑特　願　昭62－255331
㉒出　願　昭62(1987)10月9日

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明　細　書

1　発明の名称

積層セラミックスの製造法

2　特許請求の範囲

(1)　シート状に成形されたセラミックスグリーン体を、該セラミックスグリーン体の両面に電極を形成した後プリーツ状に折りたたむことによって積層体を形成し、該積層体を、焼成することを特徴とする積層セラミックスの製造法。

(2)　前記シート状に成形されたセラミックスグリーン体がセラミックス原料粉末、有機バインダー及び可塑剤を含有して成形されたものであることを特徴とする特許請求の範囲第(1)項記載の積層セラミックスの製造法。

(3)　前記シート状に成形されたセラミックスグリーン体をプリーツ状に折りたたむ際に紙折機を用いることを特徴とする特許請求の範囲第(1)項及び第(2)項記載の積層セラミックスの製造法。

(4)　前記シート状に成形されたセラミックスグリーン体を、プリーツ状に折りたたむ際に折り目を50～150℃に加勢しながら形成させて折りたたむことを特徴とする特許請求の範囲第(1)～(3)項記載の積層セラミックスの製造法。

3　発明の詳細な説明

（産業上の利用分野）

本発明は積層セラミック圧電アクチュエータ、積層セラミックコンデンサなどの積層セラミックスの製造法に関する。

（従来の技術）

積層セラミック圧電アクチュエータ、積層セラミックコンデンサなどを製造する一般的な方法は、あらかじめセラミックスグリーン体を板状に成形し、焼成した後に両面に内部電極用の電極を形成し、その後接着剤で貼り合わせて積層するか、あるいはドクターブレード法などによってシート状に成形したグリーン体の片面に内部電極として所定のパターンにペースト状の

電極材料をスクリーン印刷法などにより印刷し、その後所定枚数積層し、熱プレスにより一体化し、所定寸法に切断後、焼成を行なっている。各層を並列に電気的接続を行なうために前記の方法のいずれの場合にも最終工程として外部電極により内部電極を一層おきにプラス極とマイナス極となるように接続している。

外部電極により内部電極を並列に接続するには次の2つの方法が一般的にとられている。

これらの方法を図面に基づいて説明すると第4図及び第5図は従来の積層セラミックスにおいて、内部電極の形態及び該電極と外部電極との接続方式の例を説明する為の説明図であって各図中11は内部電極、12は外部電極、13はセラミックス、14は絶縁体を示す。従来の第1の方法は内部電極11の形成パターンを第4図に示すように一層おきに素子の一端面に露出させ、これを外部電極12により接続する方法である。また第2の方法は、第5図に示すように内部電極11の形成パターンは各層一致させ、素子端面には各層全ての内部電極の端部が露出するように配置し、この後あらたに一層おきに露出している内部電極の端部を絶縁体14によって絶縁し、残された一層おきの露出している内部電極の端部を外部電極12により接続する方法である。

（発明が解決しようとしている問題点）

内部電極を並列的に接続する方法は前記いずれの場合も、内部電極形成とは別な工程で行ない、さらに1層おきに内部電極を接続させなければならないので、高い精度と、複雑な工程が必要である。この問題は特に、セラミックスの一層がさらに薄くなる程ど、また、積層数が増加する程ど顕著となる。

例えば、一層おきに内部電極の端部を露出させ、露出していない部分を絶縁部としているタイプ（第1の方法）では、この絶縁部分は圧電アクチュエータ、コンデンサーにとっては、絶縁を保つという以外はその性能に対してなんら寄与していないのでこの部分は出来るだけ小さいことが好ましい。しかしながら通常、内部電極のパターンは、スクリーン印刷法などにより形成するので、数100μmより小さくさせることは、実際上非常に困難である。また積層数を増加させた場合この内部電極のパターンを各層一致させるためには高い精度が必要となる。一方内部電極の全層を素子端面に露出させ、端面上にあらたに絶縁層を形成させる場合（第2の方法）はセラミックス層の厚さが50μmよりも薄くなると、一層おきに絶縁を実施することは困難となるという、大きな問題点を有する。

本発明の目的はかかる問題点を解決するために、内部電極と外部電極を同時に形成させ、より薄層化、多層化を容易に行なうことが可能な積層セラミック圧電アクチュエータ、積層セラミックコンデンサーなどの積層セラミックスの製造法を提供することにある。

（問題を解決するための手段）

本発明の目的は積層セラミック圧電アクチュエータあるいは積層セラミックコンデンサーなどの積層セラミックスを、従来法の難点を克服して工業的有利に製造することにあり、しかしてかゝる本発明の目的はシート状に成形された、セラミックスグリーン体を、その両面に電極を形成した後プリーツ状に折りたたむことによって積層体を形成し、その積層体を焼成することによって容易に達成される。

以下本発明を詳細に説明する。

本発明に用いるセラミックス原料としては、圧電体として

$Pb(ZrTi)O_3$（PZT）

$(PbLa)(ZrTi)O_3$（PLZT）

あるいは

$PZT-Pb(Mg_{1/3}Nb_{2/3})O_3$

などがあり、また誘電体としては

$BaTiO_3$

$SrTiO_3$

などが挙げられる。またその製造法は通常の方法例えば、原料酸化物を混合して仮焼し、さらに粉砕したもの、あるいは共沈法によって得ら

れる粉末などが代表的に挙げられる。

粒径としては通常数μm程度の大きさのものが用いられる。より薄いシート状セラミックスグリーン体(以下、単にグリーンシートと称する。)を得るためには用いる粒子も厚さに応じて小さくする必要があるが、ドクターブレード法でシート成形を行なう場合は通常0.5〜1μm程度の粒径の粉末を用いることが好ましい。またグリーンシートを得る為に用いる有機バインダーは非水溶剤系を用いる場合はポリビニルブチラール、ポリメチルメタアクリレート、メタクリル酸エステル共重合体などであり、水系の溶剤を用いる場合にはポリビニルアルコールメチルセルロース、ヒドロキシエチルセルロース、アクリル系ポリマーなどが代表的である。また同じく可塑剤としてはジブチルフタレート、ブチルベンジルフタレート、ポリエチレングリコール、グリセリンなどが代表的である。シート成形は例えばドクターブレード法を用いるならば、前記セラミックス原料粉末、有機バインダー、可塑剤とともに適宜分散剤を加え、有機バインダー、可塑剤、分散剤を溶解する溶剤例えばエチルセロソルブ、トルエン、キシレン、ローブタノール、イソプロパノールあるいは水などとともにボールミルで15〜100hr混合し、スラリー状態にした後、脱泡を行ない、ポリエステルフィルム上にキャスティングし、乾燥後、ポリエステルフィルムから剥離することによりグリーンシートを得る。

有機バインダー、可塑剤、セラミックス原料粉末の適切な量は、後の工程でグリーンシートを折りたたむ時に曲げられた部分にクラックが入ったりあるいは切断されないように選択すべきであり、具体的には通常、

有機バインダーが　5〜15wt%、
可塑剤が　2〜15wt%、

残部がセラミックス原料粉末となる範囲から選択される。これら有機バインダーと可塑剤の量が、下限量より少ない場合は折り曲げ時クラックが発生しやすかったり、更には切断されてしまうことのおこる可能性があり、また上限値より多い場合はセラミックス原料粉末が少なすぎるために焼成後緻密な焼結体を得にくい傾向を生ずる。特に可塑剤が多い場合はグリーンシートが軟くなりすぎ、ハンドリングが困難となる。

次にグリーンシートの両面に電極を形成するには、前記得られたグリーンシートの片面にスプレー法、スクリーン印刷法などにより電極ペーストを塗付し乾燥させた後に残りの片面に同様な方法で、電極を形成する。あるいは、ポリエステルフィルム上にあらかじめ電極材料をスプレー法、スクリーン印刷法により塗布し、乾燥させた後に、ドクターブレード法によりセラミックス原料粉末を含むスラリーをこの上に、キャスティングし、乾燥後、最上面にやはり同様な方法によりもう1つの電極層を形成し乾燥する。さらに最終的にポリエステルフィルムを剥離して、両面に電極層が形成されたグリーンシートを得ることも出来る。

また両面に形成する電極は、全面に電極を形成させても、所定のパターンに従って部分的に形成させてもよい。

用いる電極材料としてはPtあるいはAg−Pd、Pt−Pd、Pd、Agなどを塗付方法に従い適宜有機バインダー、溶剤などとともに混合、分散させたものを用いる。

積層方法は、両面に電極が形成されたグリーンシートを所定の幅、長さに切断後、例えば紙折機などを用いてプリーツ状に折りたたむ。この時折りたたみを容易に行なうために、あらかじめ折り目を形成させることが好ましいが温度の低い状態で折り曲げる、あるいは折り目をつけると、クラックが入るので、折り曲げ部分を加熱しながら行なうことがクラック防止に有効である。

以上の電極形成、折りたゝみ方の一例を図面に基づいて説明すると第1図は電極付グリーンシートの一例を示した説明図、第2図は該グリーンシートの折りたゝみ方の一例を示した説明図、第3図は折りたゝみの前にグリーンシート

に折り目をつける折り目形成装置の一例を示した縦断面模式図であり、各図中1は電極付きグリーンシート、2はグリーンシートに形成された電極部分、3はグリーンシートの非電極部分、4は折り目形成装置の一対のロール、5はその突起部、6は同じくその陥没部をそれぞれ示す。

電極は前述した如くグリーンシートの両面に全面的に設けても良いが、第1図の如く適当な間隔で電極部分2と非電極部分が交互に出現し、電極部分2が若干幅広で、しかもグリーンシートの表裏において、一部に電極部分2の重複がある他は電極部分2と非電極部分3が常に共存する如く、縞模様に形成するのが好ましく、かゝるグリーンシートを折りたゝむ際は、第2図の如く電極部分2の一端2′が折りたゝみ内端に位置し、他端2″が折りたゝみ外端をほゞ完全に被覆する位置となる如く折りたゝまれる。そしてこの様な折りたゝみ方を容易にすべく第3図の如き紙折り機を用いると便利である。同図において4は周面に略三角形の突条を有する、少くともグリーンシートの幅より幅広の、一対の噛合回転ロールであって、相互の突起部5と陥没部6とが噛合うことにより電極付きグリーンシート1に上述の如き折りたゝみを実現し得る折り目を形成せしめることが可能である。なお、この折り目形成の際、突起部5と陥没部6とはグリーンシートが軟化する温度(通常50〜150℃)に加温されているとクラックや折損を防止できて好適である。

次に、プリーツ状に所定の積層数となる如く折りたゝまれた電極付きグリーンシートは、好ましくは熱プレスにかけて一体化される。以上の如くして得られたグリーンシート積層体において、グリーンシートの両面に形成された電極は、内部電極と外部電極両方を兼ねることになり、内、外電極が同時に形成されたことになる。また、一体化された積層体は、構造的には、第4図の従来積層体とほゞ同じになるが、絶縁部分の大きさは各セラミック層の厚さと同じになり、1層の厚さが薄くなればなるほど、この絶縁部分も少くなり、素子の性能に寄与しない部分を最少限に少く出来ることとなる。

次に、一体化したグリーン状態の積層体は、所定の大きさに切断後焼成し、有機物を分解除去し、さらに焼結を行ないセラミックスとする。焼成は通常空気中などの酸化雰囲気中で行ないアルミナ製の匣鉢中で0.5〜30℃/hr で昇温、400〜600℃で1〜10時間保持し、有機物を熱分解揮散させる。その後800〜1250℃で、空気中あるいは酸素中で1〜10時間程度焼結を行なう。この時PZTのように鉛の化合物は焼成中鉛が蒸発するので、鉛雰囲気調製用の粉末例えば $PbZrO_3$ あるいは $PbZrO_3-ZrO_2$ 混合物などを同じ匣鉢中に入れて一緒に焼成する。

得られた積層セラミックスは圧電体であれば分極処理を行ないリード線の半田づけを行なう。

以下、実施例によって、本発明を更に具体的に説明するが、本発明はその要旨を越えない限り、下記実施例によって限定されるものではない。

<実施例1>

(1) グリーンシートの作製

セラミックス原料粉末として市販のチタン酸ジルコン酸鉛60A(富士チタン工業株式会社製;平均粒径約1μm)60.1g、有機バインダーとしてポリビニルブチラールBM-1(積水化学工業株式会社製)4.8g、可塑剤としてジブチルフタレート2.8g、分散剤1.7g、溶剤としてエチルセロソルブ16.7gをボールミルを用いて48時間混合した。得られたスラリーの粘度はブルックフィールド型粘度計を用いて3000cps(12rpm、20°)であった。

このスラリーをポリエステルフィルム上にキャスティングし、ドクターブレード法によりシート成形を行なった。乾燥後ポリエステルフィルムからハクリしてグリーンシートを得た。この時得られたシートの厚さは70μmであった。

電極の塗付はスクリーン印刷法により、片面ずつPtペーストを塗付した。用いたスクリーンは350メッシュのステンレス製であった。また塗付した電極は、グリーンシートの全面にベタ塗りした。

(2) 積　層

(1)で得られた両面に電極が形成されたグリーンシートを幅5cm、長さ1mの帯状に切断した後、第3図に示した様な折り目形成用の治具を通し折り目をつけた。この時折り目と折り目の間隔は12mmであった。また折り目形成治具はあらかじめ80℃になるように加温されている。

折り目のついたグリーンシートは容易に折りたたむことが出来るので折りたたんだ後に長さ5cm、幅1.2cm、深さ5cmの金型中に入れ、減圧脱気下、80℃ 5時間圧力5kg/cm²で加熱圧着を行ない積層一体化した。

得られたグリーン状態の積層体は1層7μm 83層で全体の大きさは長さ5cm、幅1.2cm、厚さ約0.6cmであった。

(3) 焼　結

上記グリーン状態の積層体をアルミナ質の鉢中に鉛雰囲気調製用にジルコン酸鉛を入れ、アルミナ製のふたをして500℃までは10℃/hrで昇温し、その後500℃で4時間保持した。次いで150℃/hrで昇温し1250℃で1時間保持して焼結を行ない、積層セラミック圧電体を得た。

<実施例2>

特公昭55－34524号公報 実施例1で示される共沈法にて得られた $Pb_{0.91}La_{0.09}(Zr_{0.65}Ti_{0.35})_{0.9775}O_3$ 粉末をセラミックス原料粉末として使用した以外は実施例1と同様にして、積層セラミック素子を製造した。

得られた積層セラミック素子は電気光学素子として、光シャッター等にも有用である。

<実施例3>

折りたたみを紙折機(株式会社筑紫製700型)を用いて行なった以外は、実施例1と同様にして行ない、積層体を製造した。

<実施例4>

グリーンシートの両面に形成する電極のパターンを第1図に示すように形成し、折りたゝみ方を第2図の如く行った以外は実施例1と同様にして、各セラミックス層間に一層の電極を有し、外部電極への接続が極めて容易なセラミックス積層体を得た。

(発明の効果)

以上説明したように、この発明はシート状に成形されたセラミックス原料粉末有機バインダー、可塑剤からなるセラミックスグリーンシートの両面に電極を形成させ、プリーツ状に折りたたむことによって積層体を作り、その後焼成して、積層セラミック圧電アクチュエータや、積層セラミックコンデンサーを製造するようにしたので、内部電極と外部電極を同時に形成させることが可能になり、積層体の1層のより薄層下、及びより多層化を容易に製造できる利点を有する。

4 図面の簡単な説明

第1図は電極付グリーンシートの一例を示した説明図、第2図は該グリーンシートの折りたたみ方の一例を示した説明図、第3図は折りたたみの前にグリーンシートに折り目をつける折り目形成装置の一例を示した縦断面模式図であり、各図中1は電極付グリーンシート、2はグリーンシートに形成された電極部分、3はグリーンシートの非電極部分、4は折り目形成装置の1対のロール、5はその突起部、6は同じくその陥没部をそれぞれ示す。また第4図及び第5図は従来用いられている積層セラミック圧電アクチュエーターあるいは積層セラミックコンデンサーの説明図であり、各図中、11は内部電極、12は外部電極、13はセラミックス、14は絶縁体をそれぞれ示す。

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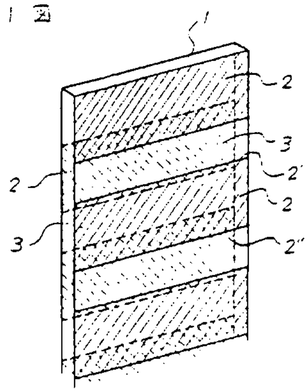
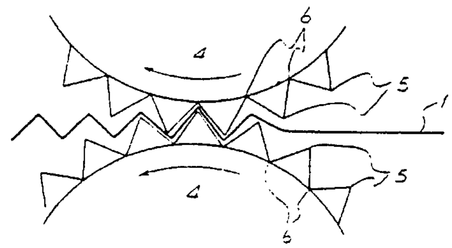
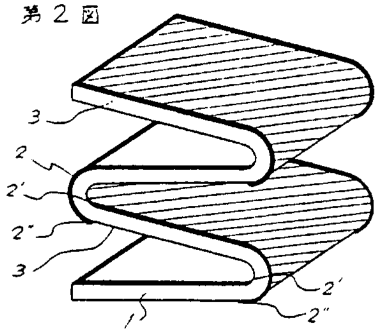
第1図



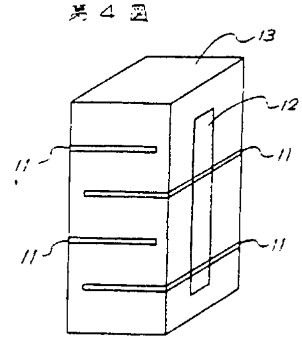
第3図



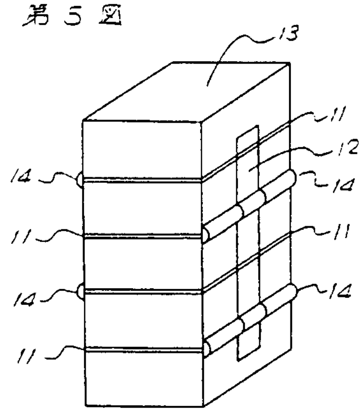
第2図



第4図



第5図



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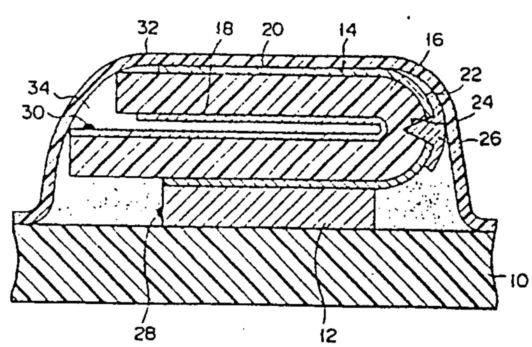
(54) **Ultrasonic transducer with a multiple-folded piezoelectric polymer film.**

(57) An ultrasonic transducer includes a piezoelectric polymer film (14) folded as at least two layers and having electrodes on both the surfaces thereof The ultrasonic transducer is responsive to a signal, applied across electrodes, to produce an ultrasonic wave to be focused at one spot so that it is converted to an electric signal. In this ultrasonic transducer, a groove (24) or through holes (42) are formed on and along the folded area (22) of the piezoelectric polymer film.

F I G. 3



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Croydon Printing Company Ltd.

Ultrasonic transducer with a multiple-folded piezoelectric polymer film

This invention relates to an ultrasonic transducer with a multiple-folded piezoelectric polymer film.

In general, as a linear array type ultrasonic transducer for use on a linear electron scanning system use may be made of an array type in which a ceramics piezoelectric substratum, such as lead titanate or lead titanate zirconate, includes strip-like elements. This type of ceramics piezoelectric substratum is hard and brittle in nature and tends to produce defects and cracks when the strip-like elements are obtained. Furthermore, it is difficult to precisely form many strip-like elements. Many problems are also involved from the standpoint of manufacturing costs.

It is known that a fluorine-containing high polymer, such as polyvinylidene fluoride (PVF_2) or polyvinylidene-triethylene fluoride copolymer ($PVF_2 \cdot TrFE$), or the other organic synthetic high polymer is polarized at high temperatures under a high electric field to manifest its piezoelectricity and pyroelectricity. Recently, an ultrasonic transducer has actively been developed utilizing the thickness shear mode of the piezoelectric high polymer. The specific acoustic impedance of this piezoelectric polymer is close to that of a human body and, moreover, a smaller elasticity is involved on the piezoelectric

polymer. It is said that, if the piezoelectric polymer is applied to a linear array type ultrasonic transducer, it is unnecessary, unlike the ceramics piezoelectric substratum, to obtain strip-like elements by a cutting operation or a separating operation.

The dielectric constant of the piezoelectric polymer film is, in general, of the order of 10, i.e., prominently smaller than that of the ceramics piezoelectric substratum. Furthermore, the drive elements of the linear array type ultrasonic transducer have a smaller area and an extremely high acoustic impedance. Usually, a poor matching is involved against a 50 Ω power source (transmitting/receiving circuit), suffering an appreciable loss on the ultrasonic transducer.

In order to solve the above-mentioned problems, an ultrasonic transducer has been proposed in which a plurality of piezoelectric polymer films are properly piled up to obtain a thicker polymer film while at the same time the electric impedance is lowered. This type of conventional ultrasonic transducer is shown in Fig. 1. In the conventional ultrasonic transducer, a plurality of piezoelectric polymer films (3, 3, 3), each, have strip-like electrodes 1 on one surface and a common electrode 2 on the other surface and are piled up such that the two adjacent piezoelectric polymer films have their identical electrodes located opposite to each other as shown in Fig. 1. The opposite, identical electrodes of the adjacent two polymer films are connected by a solder or a conductive adhesive 4 to each other. For example, the strip-like electrode 1 of the first piezoelectric polymer film is located opposite to the strip-like electrode 1 of the corresponding adjacent second piezoelectric polymer film. Such a type of ultrasonic transducer is known which lowers an electric impedance. With Zo representing an electric impedance of, for example, a single layer of a resonant frequency f,

$$Z = Zo/n^2 \quad \text{(n: the number of layers)}$$

for the ultrasonic transducer of the configuration as shown in Fig. 1. An electric impedance of 1/4 is involved for a two-layer structure and an electric impedance of 1/9 is involved for a three-layer structure. It is, therefore, possible to obtain an improved matching with respect to a power source. In the conventional arrangement as shown in Fig. 1 it would be difficult to take leads 5a and 5b out of the electrodes 1 and 2, respectively.

An ultrasonic transducer of such a type as shown in Fig. 2 has also been proposed which has a continuous, piezoelectric polymer film 3a properly folded as a multiple-layer structure of a desired thickness. In this transducer, it is easier to take leads from the corresponding electrodes and it is also possible to lower the electric impedance. However, the following problems arise therefrom.

That is, if a continuous, piezoelectric polymer film is to be folded, it would be difficult to precisely locate the corresponding areas of the strip-like electrodes opposite to each other. In this case, a possible displacement is produced in the vertical directions of the electrodes 1, causing a difference in the electric impedance of drive elements and producing a possible shorting between the drive elements. This problem becomes prominent with an increase in the number of layers so piled up.

It is accordingly an object of this invention to provide an ultrasonic transducer having a piezoelectric polymer film which is readily folded as a multiple-layer structure and which assures a ready, accurate alignment between the opposite areas of corresponding electrodes.

According to this invention there is provided an ultrasonic transducer including a piezoelectric polymer film having electrodes on both the surfaces thereof

and folded as at least two layers, the piezoelectric polymer film being responsive to a signal applied to the electrodes to generate an ultrasonic wave focused on one spot and being adapted to receive an ultrasonic wave to convert it to an electric signal, in which a groove is formed along a folding line on the piezoelectric polymer film.

This invention will be explained below with reference to the accompanying drawings.

Figs. 1 and 2 are cross-sectional views showing a conventional ultrasonic transducer;

Fig. 3 is a diagrammatic, cross-sectional view showing an ultrasonic transducer according to a first embodiment of this invention;

Fig. 4 is a perspective view diagrammatically showing a state previous to that in which a piezoelectric element of the ultrasonic transducer as shown in Fig. 3 is folded;

Figs. 5 to 7 are cross-sectional views diagrammatically showing a modified form of piezoelectric film with respect to the ultrasonic transducer of this invention;

Fig. 8 is a cross-sectional view diagrammatically showing an ultrasonic transducer according to a second embodiment of this invention;

Fig. 9 is a perspective view diagrammatically showing a state previous to that in which a piezoelectric film of the ultrasonic transducer of Fig. 8 is folded; and

Figs. 10 and 11 are cross sectional views diagrammatically showing a piezoelectric film of a conventional ultrasonic transducer for use in explaining an advantage of the embodiment of this invention.

The embodiments of this invention will be explained below by referring to Figs. 3 to 11 of the accompanying drawings.

First, an ultrasonic transducer according to the

embodiment of this invention will be explained below in more detail by referring to Figs. 3 to 7.

In Fig. 3, reference numeral 10 shows a support made of, for example, an acrylic resin. A copper plate 12 is fixed on the support 10 and serves as a 200 μm-thick sound reflecting plate and a common electrode. A once-folded piezoelectric film 14 is disposed on the copper plate 12 and has a PVF_2 piezoelectric element 16. A plurality of strip-like electrodes 18 made of silver are equidistantly provided on one surface of the piezoelectric element 16 and a common electrode 20, made of silver, is provided on the whole area of the other surface of the piezoelectric element 16. At the common electrode of the PVF_2 piezoelectric element 16 a V-shaped groove 24 is formed on a substantially central portion of a folded area 22 of the piezoelectric element 16 such that it is located along the folding line, i.e., in a direction perpendicular to that in which the strip-like electrode 18 extends. The V-shaped groove 24 is formed across substantially one half of the thickness of the piezoelectric element with the common electrode 20 separated.

Fig. 4 is a perspective view showing a state before the piezoelectric film 14 is folded. The piezoelectric body as shown in Fig. 4 is folded back upon itself along the folding line with the V-shaped groove 24 located at the outer side as shown in Fig. 3.

The folded piezoelectric film 14 is disposed on the copper plate 12 such that the common electrode 20 is in contact with the copper plate 12.

The common electrode 20, though separated by the V-shaped groove 24 as set out above, has its separated areas mutually connected by, for example, a conductive paste 26 which is deposited at and near the V-shaped groove 24 as shown in Fig. 3. As the conductive paste use may be made of an epoxy resin mixed with carbon,

copper or silver powders.

The folded piezoelectric film 14 is manufactured by the following method.

An about 1 μm-thick silver layer is deposited by, for example, a vacuum deposition method on both the surfaces of an about 50 μm-thick PVF_2 film which is obtained by a uniaxial stretching method. The resultant structure is polarized under an electric field of 6 KV at 100°C for 1 hour and then cooled down to room temperature to yield a PVF_2 piezoelectric element 16. In this case, one surface of the PVF_2 film is subjected to a patterning as shown in Fig. 4, forming a plurality of strip-like electrodes 18 in a manner to be in parallel with the direction in which uniaxial stretching is carried out. As the strip-like electrodes, 64 unit electrode elements are formed having a dimension of about 0.9 mm in width × about 35 mm in length with an element-to-element gap of about 0.1 mm. The other surface of the PVF_2 film is subjected to a patterning to form the common electrode 20 made of silver. A V-shaped groove 24 of about 30 μm in depth × about 0.2 mm in width is formed by, for example, a cutter along a folding line. The resultant structure is folded back upon itself once along the V-shaped groove 24 to provide the above-mentioned PVF_2 piezoelectric film 14. Then, a conductive paste 26 is deposited at and near the V-shaped groove 24 and dried to provide a folded piezoelectric film 14 in which the common electrode areas separated by the V-shaped groove are connected to each other. A lead 28 is connected to the copper plate 12 and a lead 30 is connected to the respective strip-like electrode 18 of the folded piezoelectric film 14 such that it is located at one end portion of the piezoelectric film 14 and on the inner side of the folded piezoelectric film 14. A polyester film of, for example, 12 μm in thickness is covered on the resultant structure, noting that an epoxy resin 34

is filled in a space between the polyester film 32 and the piezoelectric structure. The epoxy resin 34 is commercially available under the trade name of 301-2 manufactured by Epotek Co., Ltd. The presence of the epoxy resin 34 positively retains the state in which the piezoelectric film 14 is folded back upon itself, and also assures a positive fixing of the piezoelectric film 14 to the support 10.

In the embodiment of this invention, a folding operation can readily been carried out, since the V-shaped groove 24 is formed on one surface, for example, on the common electrode side, of the PVF_2 piezoelectric structure to be folded back upon itself. This specific arrangement permits the upper portion of the folded piezoelectric structure to be accurately aligned with the lower portion thereof in a substantially parallel array. As a result, there is no possibility that the impedance of drive elements will vary due to a misalignment between the oppositely facing strip-like electrodes of the folded piezoelectric structure and that short-circuiting will occur between the drive elements. It is therefore possible to obtain a linear array type ultrasonic transducer of high reliability.

In actual practice, the linear array type ultrasonic transducer was measured, but no electric impedance variation was not observed across the unit electrode elements. When a pulse voltage was applied between the common electrode 20 and eight of the unit electrode elements, the ultrasonic transducer was operated at a frequency of 5 MHz.

The PVF_2 piezoelectric transducer may be formed in a multiple-folded fashion to obtain a linear array type ultrasonic transducer of a low electric impedance. Even in this case, it is possible to readily perform such a folding operation.

Furthermore, a V-shaped groove 24 is formed along

each folding line, preventing the folded area from being extremely bulged.

It has been confirmed that, if the folded area of the conventional piezoelectric body as set out below is bulged as shown in Fig. 11, an electric loss or an "electric stroke" occurs on the bulged area, or an acoustic coupling, for example, occurs there, causing a disturbance of ultrasonic radiation beams.

In the embodiment of this invention it is possible to prevent such an electric loss or a possible disturbance of ultrasonic radiation beams, because there is no bulging area at the folded area of the piezoelectric film. It is therefore, possible to obtain an ultrasonic transducer assuring an excellent performance.

In the embodiment of this invention, the groove 24 is provided on one surface, for example, on the common electrode side, of the piezoelectric film 14 such that their separated areas of the common electrode are electrically connected through the conductive paste or metal film 26 deposited at or near the groove 24. However, this invention is not restricted thereto. For example, the metal film 26 for electrical connection may be provided, by a vapor deposition method or a sputtering method, on the V-shaped groove 24 at the folded area 22 of the piezoelectric film 14 as shown in Fig. 5.

As shown in Fig. 6, the piezoelectric film may be folded back upon itself with a V-shaped groove 24 internally formed along a folding line on the opposite, inner, common electrode 20 areas of the piezoelectric film. In this case, a conductive paste 26 may be deposited at the V-shaped groove 24 to permit the separated areas of the common electrode to be connected together.

Where the piezoelectric film 14 is folded back upon itself with the groove 24 inside, it is still possible to locate a conductive plate 38 at a proper place

between the opposite, inner, common electrode areas to permit an electrical connection to be made therebetween.

The leads 28 and 30 may be connected at any place to the common electrode 20 and strip-like electrode 18, respectively. For example, the leads 28 and 29 may be connected to the corresponding electrodes, respectively, such that, as shown in Fig. 5, the lead 30 extends on the upper side of the electrode 20 and the lead 28 extends on the lower side of the electrode 18.

An ultrasonic transducer according to a second embodiment of this invention will be explained below by referring to Figs. 8 and 9. The same reference numerals are employed to designate parts or elements corresponding to those shown in the first embodiment of this invention. Further explanation is therefore omitted.

In the ultrasonic transducer according to a second embodiment, two folded areas 22, 22 are formed on a piezoelectric element 16 to provide a three-layer piezoelectric structure as shown in Fig. 8. Through holes 40, 42 are formed at the folded areas of the piezoelectric element in place of the V-shaped groove 24 set out above.

That is, the through holes are formed, in two rows, at those locations adjacent to strip-like electrodes 18 on a piezoelectric film 14 such that they are located in a directon perpendicular to that in which the strip-like electrodes 18 extend. The piezoelectric film 14 is folded, along the two rows (40, 42) of the through holes, with an adhesive layer 34A initially coated thereon, providing the piezoelectric film structure with the adhesive layer filled therein.

The piezoelectric film 14 is manufactured as follows:

First, an about 1 μm-thick silver layer is deposited by, for example, a vacuum deposition method on both the surfaces of an about 50 μm-thick PVF_2 film

which is obtained by a uniaxial stretching step. The resultant structure is polarized under an electric field of 6 KV at 100°C for one hour and cooled down to room temperature to provide a PVF_2 piezoelectric structure. In this case, a silver layer on one surface of the piezoelectric structure is subjected to a patterning as shown in Fig. 9 to provide strip-like electrodes 18 in a direction parallel to that in which uniaxial stretching is carried out. As the strip-like electrodes 18, 64 unit electrode elements are formed each having a dimension of 0.9 mm in width × 45 mm in length with an element-to-element gap of 0.1 mm. The silver layer on the other surface of the piezoelectric structure is subjected, as required, to a patterning to provide a common electrode 20. Then, small through holes (40, 42) of about 50 μm in diameter are formed, by a laser beam, in two rows on those fold formation areas 22 which are adjacent to the strip-like electrodes 18. Then, the resultant PVF_2 piezoelectric structure 14 is folded along two rows (40, 42) of the through holes to provide an S-shaped (three-layered) piezoelectric structure as shown in Fig. 8 with an epoxy resin series adhesive cemented by a press. The adhesive is commercially available under the trade name of 301-2 manufactured by Epotek Co., Ltd. A lead 28 is connected to a copper plate 12 and a lead 30 is connected to the respective strip-like electrode 18. A polyester film 32 of, for example, 12 μm in thickness is covered on the piezoelectric structure to provide a ultrasonic transducer as shown in Fig. 8 in which the adhesive (301-2) is occupied therein. In this connection it is to be noted that the piezoelectric structure is supported on a support 11.

According to the second embodiment of this invention, although the piezoelectric structure is folded along the two rows (40, 42), it is possible to obtain the same effects as shown in the first embodiment

of this invention. Furthermore, it is not necessary to employ any conductive paste for electrical connection, because the respective electrodes are not electrically separated by the through holes (40, 42). The adhesive layer 34A is passed through the through holes (40, 42) of the piezoelectric film 14 to suppress the bulging of the folded area to a small extent. At the same time, any excessive amount of adhesive in the layer-to-layer gap can be removed to form a very uniform, thin adhesive layer 34A. When, therefore, the ultrasonic transducer is operated, it is possible to eliminate a possible acoustic coupling and "electric stroke" at those areas adjacent to the strip-like electrodes where no voltage is applied.

When a length of a piezoelectric polymer 3a is doubled back upon itself as shown in Figs. 10 and 11, a force acts in a direction as indicated by arrows B, causing the adhesive to be moved toward the folded area (i.e. in a direction as indicated by an arrow A) where it is concentrated to cause the folded area to be bulged as shown in Figs. 10 and 11.

In the ultrasonic transducer according to the second embodiment of this invention no bulging occurs, since no excessive amount of adhesive flows toward the folded area due to the presence of the holes 40, 42. Furthermore, when the PVF_2 piezoelectric film 14 is to be multiple-folded to provide a linear array type ultrasonic transducer of a low electric impedance, a folding operation can be readily effected along the through holes (40, 42).

According to this invention, since the through holes (40, 42) are formed on the folded area of the PVF_2 piezoelectric film 14, an extra amount of adhesive is passed out through the through holes (40, 42) during the folding/cementing step to obtain an integral unit. It is also possible to obtain a modified form of PVF_2 piezoelectric film which includes, for example, a

continuous, vertical, multi-folded structure including concave layers.

According to this invention, the through holes, though formed by a laser beam on the PVF_2 piezoelectric film, may be formed by, for example, a melting method or a mechanical method on the PVF_2 piezoelectric film.

It is desirable for the through holes to be formed on the non-working areas between the respective strip-like electrodes as in the second embodiment. However, they are formed on the strip-like electrodes so far as the operation of the ultrasonic transducer is not affected by the configuration of the strip-like electrodes. The through holes may also be formed on the boundary area between the working and non-working areas if a narrow gap is defined between the strip-like electrodes.

This invention is not restricted to the above-mentioned embodiments. Various changes or modifications may be made without departing from the spirit and scope of this invention.

For example, the piezoelectric film may be formed with four or more folding areas, instead of being formed with two or three folding areas.

According to the above-mentioned embodiments, as the PVF_2 piezoelectric body use is made of a piezoelectric material, but use may also be made of a fluorine-containing synthetic high polymer, such as TrFE, or the other organic high polymers showing the piezoelectricity, or a complex piezoelectric film prepared by mixing with a high polymer resin a ceramics type piezoelectric powder such as powdered lead titanate or lead titanate zirconate.

Claims:

1. An ultrasonic transducer including a piezoelectric polymer film having electrodes on both the surfaces thereof and folded as at least two layers, said piezoelectric polymer film being responsive to a signal applied to the electrodes to generate an ultrasonic wave focused on one spot and being adapted to receive an ultrasonic wave to convert it to an electric signal, characterized in that a groove (24) is formed along a folding line on said piezoelectric polymer film (14).

2. The ultrasonic transducer according to claim 1, characterized in that said groove (24) on a folded area (22) of said piezoelectric polymer film is formed on a side on which an outside electrode of said electrodes is located.

3. The ultrasonic transducer according to claim 1, characterized in that said groove (24) on a folded area (22) of said piezoelectric polymer film is formed on the side of said electrode (20).

4. The ultrasonic transducer according to claim 1, characterized in that said groove (24) on a folded area (22) of said piezoelectric polymer film extends along said folding line to separate one of said electrodes into two areas, said two areas of said one electrode being electrically connected to each other through a conductive material (26).

5. The ultrasonic transducer according to claim 1, characterized in that said groove (24) on the folded area of said piezoelectric polymer film is V-shaped in cross section.

6. The ultrasonic transducer according to claim 4, characterized in that said conductive material (26) is covered on said groove on the folded area (22) of said piezoelectric polymer film, said conductive material being made of a conductive paste.

7. The ultrasonic transducer according to claim 4, characterized in that said conductive material is occupied as a hard conductive layer in a space between the opposite layers of said folded piezo-electric polymer film and serves as a spacer (38) and said electrode areas separated by said groove are electrically connected to each other through said spacer, said spacer supporting said piezoelectric polymer film in place to leave a substantially uniform layer of said conductive layer between the opposite layers of said folded piezoelectric polymer film.

8. An ultrasonic transducer including a piezoelectric polymer film (14) having electrodes on both the surfaces thereof and folded as at least two layers, said piezoelectric polymer film being responsive to a signal applied to the electrode to generate an ultrasonic wave focused on one spot and being adapted to receive said ultrasonic wave to convert it to an electric signal, characterized in that holes (40, 42) are formed along a corresponding folding line on said piezoelectric polymer film.

9. The ultrasonic transducer according to claim 8, characterized in that said holes on the folded area (22) of said piezoelectric polymer film extend through said piezoelectric polymer film.

10. The ultrasonic transducer according to claim 9, characterized in that said piezoelectric polymer film (14) has a common electrode (20) formed at the whole area of one surface of the film and strip-like electrodes equidistantly formed on the other surface of said film and said through holes (40) are formed at an area between said strip-like electrodes.

FIG. 1

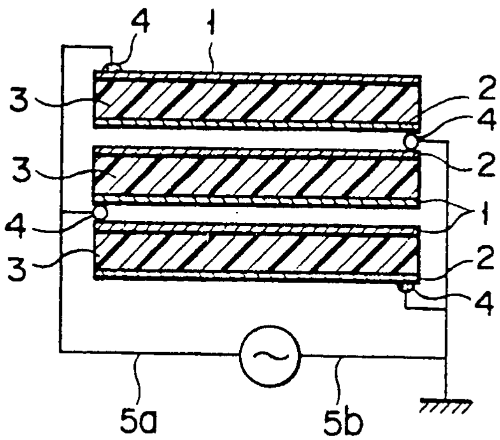

FIG. 2

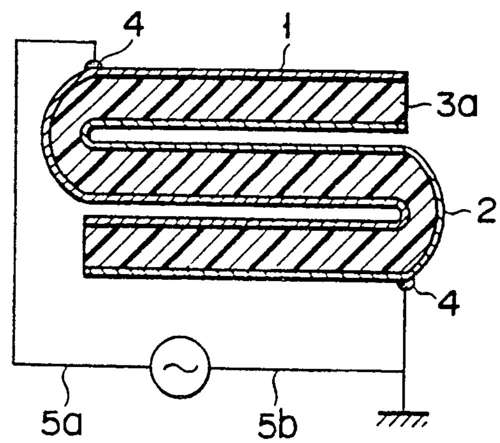

FIG. 3

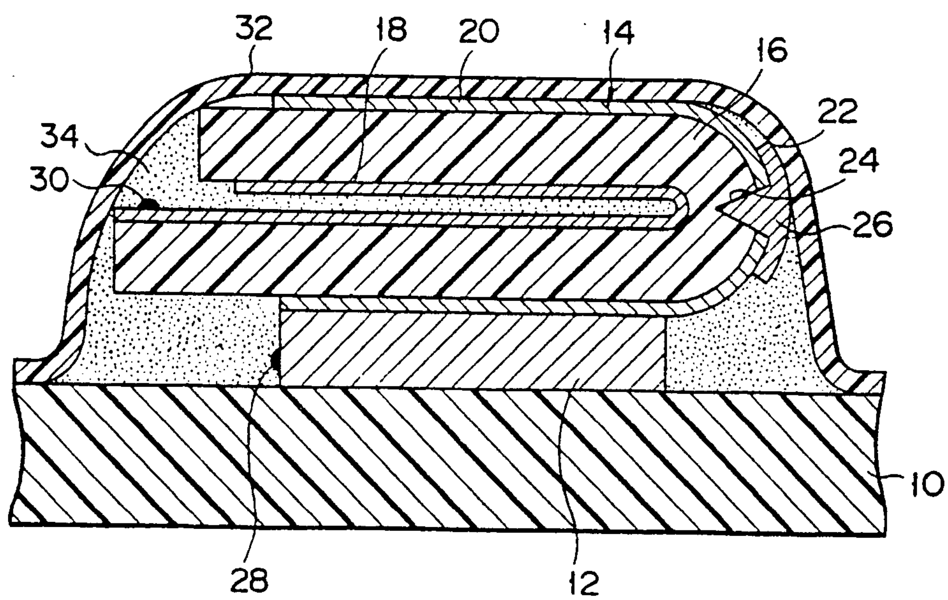

FIG. 4

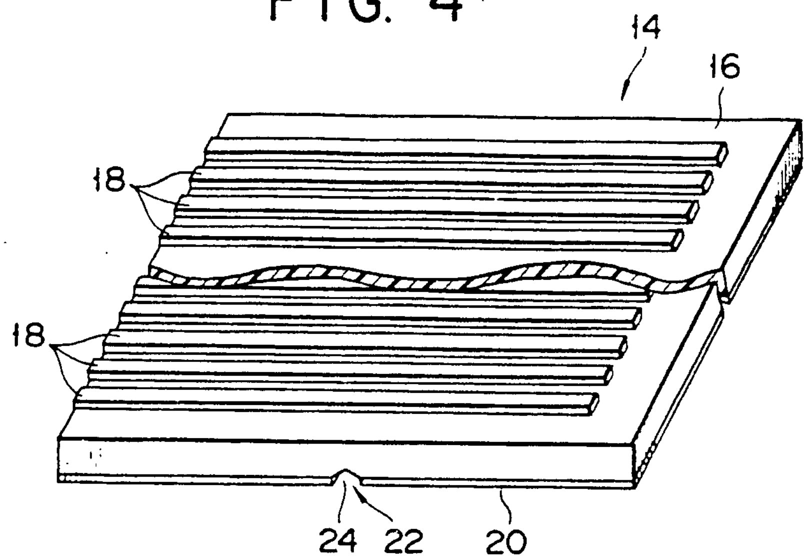

FIG. 5

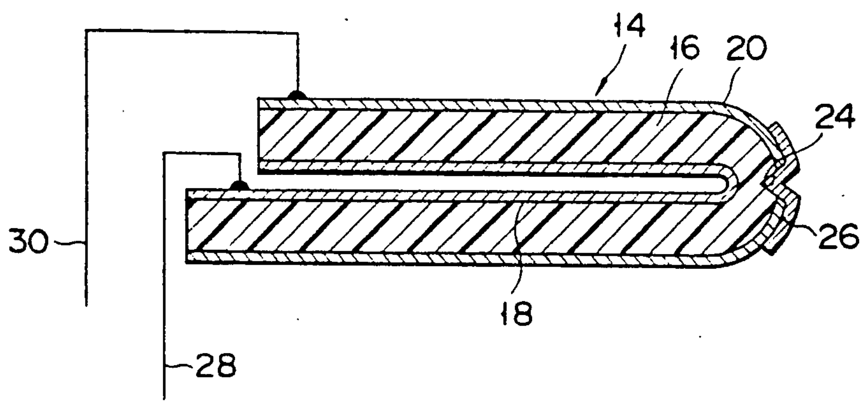

FIG. 6

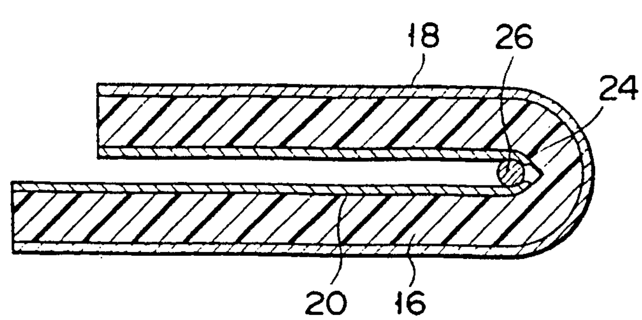

FIG. 7

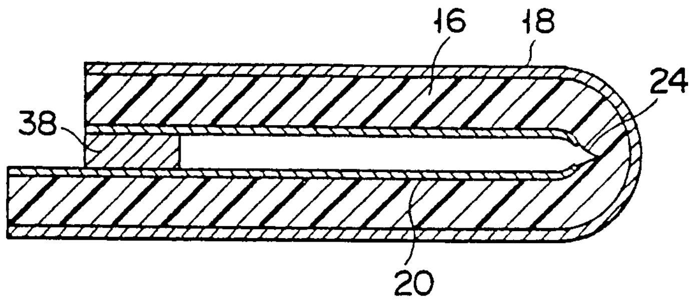

FIG. 8

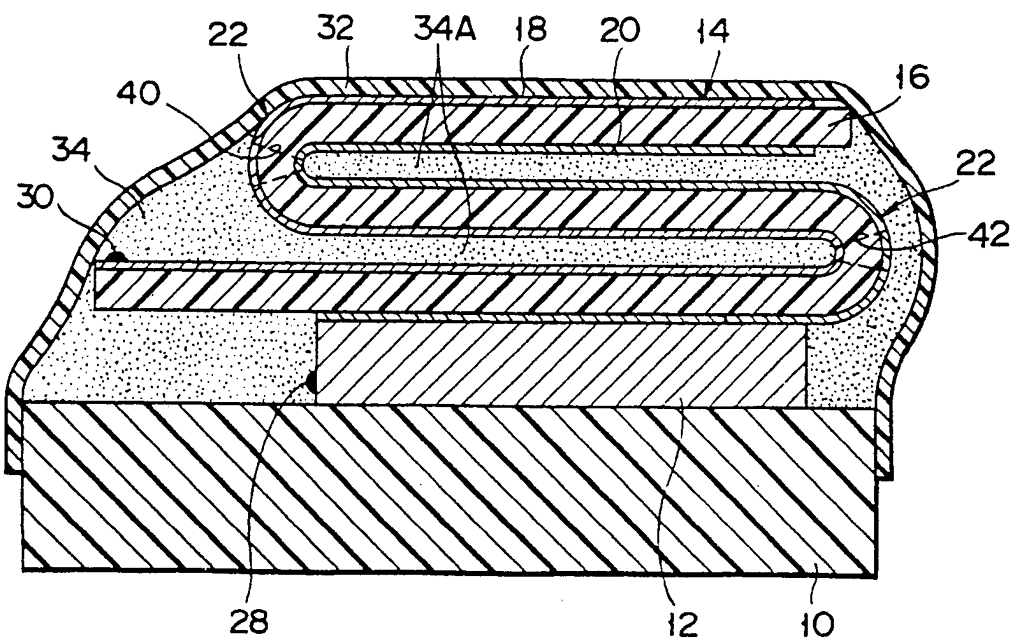

FIG. 9

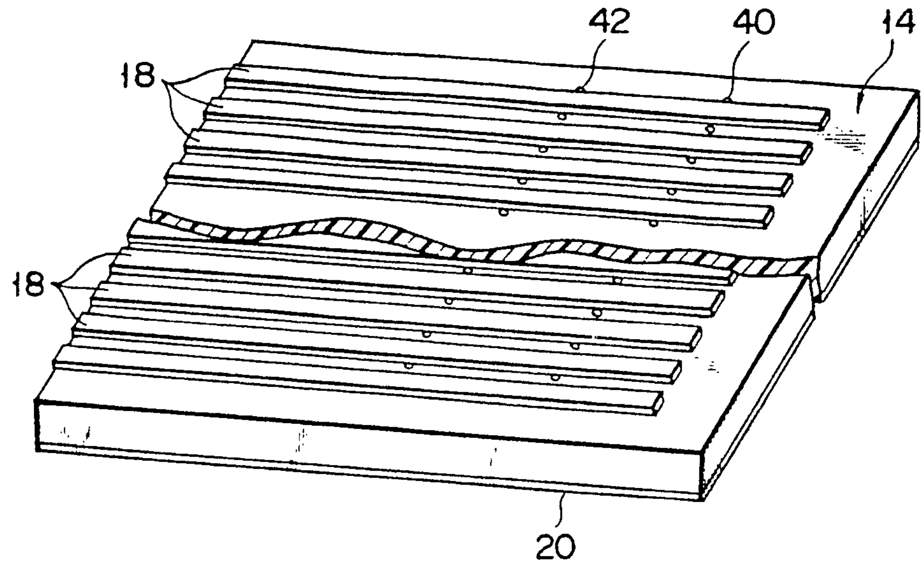

FIG. 10

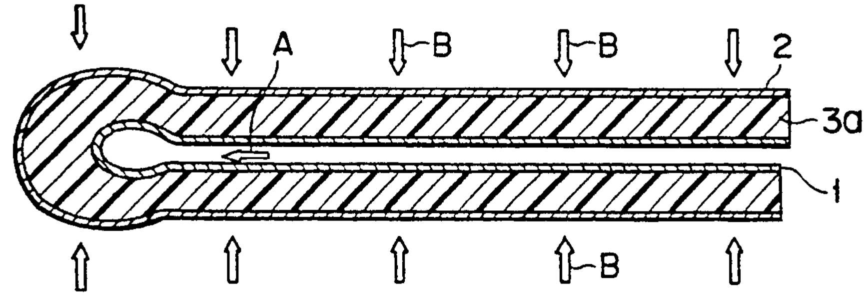

FIG. 11